Modelling Monthly and Annual variations in precipitation across Geopolitical Zones in Nigeria.

[*1]Wale-Orojo, O. A., [1]Muhammed, O. D., [1]Akintunde, A. A., [1]Dawodu, G. A., [2]Atanda, D. O. and [1]Adetona, B. O.

[1]Department of Statistics, Federal University of Agriculture Abeokuta, Ogun State, Nigeria.

[2]Mathematics Unit, St. Andrews College, Cambridge, England.

*Corresponding Author's E-mail: wale-orojooa@funaab.edu.ng , +2348037394875.

ABSTRACT

Rainfall is a major component of the water cycle, and it is responsible for depositing most of the fresh water on the earth. It provides suitable conditions for many types of ecosystems, as well as water for hydro-electric power plant and crop irrigation. Climate change and its potential impacts have become pressing global concerns, making a thorough understanding of rainfall patterns in specific regions crucial for sustainable development and disaster management. This research presents an analysis of rainfall across Nigeria by investigating the variations in rainfall distribution and intensity over different regions and time periods. This work utilizes historical meteorological records from the NASA Access Data Viewer platform. Spatial and trend analysis techniques are employed to identify areas with significant differences in precipitation amounts and variations. Markovian modelling was also introduced to model the rainfall dynamics. This enabled the forecast of probabilities of occurrence. Temporal trends are examined to detect any long-term patterns or shifts in the occurrence of rainfall events. This study showed that rainfall variability over time follows a trend within a certain arbitrary boundary with many states now witnessing greater annual rainfall, but with high variability within the rainy months of the year. The change in the pattern of rainfall has led to widespread extreme events and a reduction in the length of the growing season across the country. Such prolonged variability in rainfall may have a significant effect on the groundwater resources and the hydrology of Nigeria. Therefore, farmers should endeavour to adopt crops that are drought resistant and early maturing especially in the Northern region of the country. Other adaptive measures for climate change include users adjusting their farming calendars for irrigated agriculture according to the changing rainfall period. It is believed that these recommendations among others could help avert the impending food insecurity in Nigeria, particularly as the population has been predicted to double by the year 2050.

Keywords: Rainfall pattern, Binomial process, Realization, Random Walk, Overfitting, Underfitting.

1.0 Introduction

Variability of rainfall can be used to characterize the climate of a region. Rainfall in Nigeria is subjected to wide variability both in time and space. This variability has assumed a more pronounced dimension as a result of climate change. Rainfall pattern also enhance wind erosion/dissertation, soil erosion and coastal flooding in the north, east and coastal areas of Nigeria. In Nigeria, rainfall variability increases from the northwest to the southwest, while between year (yearly) rainfall variability increases from the north central to the southwest (Nnaji et al., 2014). Rainfall variability over time follows a spatial trend within a certain arbitrary boundary (Laux et al., 2010; Mudita et al., 2008). Rainfall pattern variability on the other hand is the degree to which rainfall amounts vary across an area or through time. This research is crucial as previous endeavours has not adequately covered trend analysis and modelling of rainfall as a dynamical system, in this research rainfall variations are analysed in a monthly and annual basis over a 40 years period. The trend analysis allows the identification of long-term patterns, helping in water resources management and disaster preparedness, and introducing Markovian modelling adds a dynamic dimension, enabling us to forecast future rainfall probabilities. This dual approach provides a comprehensive understanding, essential for sustainable development, climate adaptation, and informed decision making in Nigeria. The strategic aim of the research is to be able to avoid future causes of flooding and to examine anomalies in rainfall in some cities in Nigeria.

Nigeria is a country located in West Africa with a diverse climate. In the south, the climate is generally hot and humid, while in the north, the climate is more arid. The country receives most of its rainfall between April and October, with the peak rainfall occurring in July. However, rainfall patterns in Nigeria have become increasingly varying in recent years, with some parts of the country experiencing more frequent and intense droughts, while other parts are experiencing heavier rainfall. Odjugo (2005) work on the rainfall patterns and its implication in Nigeria showed that rainfall decreases from 1350mm (1941-1970) to 1276mm (1970-2002). His work revealed that there is a general decrease in rainfall amount in Nigeria while the coastal area is experiencing slight increase. Apart from the general southward shift in rainfall patterns, the duration has also reduced from 80-360 (1941-1970) rainy days to 40-280 (1970-2002) rainy days per year. This has created ecological destabilization and altered the pattern of the vegetation belt especially in the northern part of the country. Investigations on the impacts of greenhouse warming had suggested that the timing and regional pattern of precipitation will change and more intense of rainfall is expected (Feng, et al., 2019; Tabari, 2020).

Omogbai (2010) determined the rainy days of the first and last two months in the rainy season, including their totals in South-western Nigeria. He collected rainfall data from Akure, Benin City and Ibadan. The work revealed that most times there were cases of flood in those cities. Stepwise multiple regression analysis was used to construct a model. His analysis showed that the hypothesized rain-engendering factors were adequate in predicting rainy days in South-western Nigeria. Abdullahi et al., (2015) examined the trends in variability and spatial distribution of annual rainfall over southern Nigerian for a period 1970-2012. The nonparametric Mann-Kendall test was used to determine the statistical significance of trends while the magnitude of trends was derived from the Sen slope estimator. Map of rainfall trends was generated by applying a geo-statistical interpolation technique to visualize the detected tendencies. The findings revealed that a significant positive increase of 2.16mm in rainfall was recorded in the entire northern Nigeria within the period of 1970 to 2012. Ajayi, et al. (2018) delve into the evolving climate of Nigeria by analysing long-term trends in precipitation and temperature, the research underscores the significance of understanding rainfall patterns in the context of broader climate changes. By examining data spanning several decades, they uncover distinct trends that shed light on the changing nature of Nigeria's climate. The study's insights contributed to the growing body of research addressing climate variability and its implications for water resources, agriculture, and societal planning. Akintunde et al (2008) used a modified stochastic model for the analysis of rainfall data. The study revealed that there is high probability of rainfall occurrence.

Other study on rainfall modelling includes that of Ojo and Ogunjo (2022). Their study used multivariate polynomial regressions and machine learning algorithms for prediction of rainfall in Nigeria. Oguntade et al. (2024) did a comparative study of exponential family of distribution for modelling rainfall data.

Most of the previous work on Nigerian rainfall pattern were presented as static models. Akintunde et al (2008) handled rainfall pattern as a dynamic problem in which they were only interested in describing the long-term behaviour of the weather pattern in Nigeria without presenting a model that can adequately mimic this behaviour. The aim of this study is to identify a dynamic model for predicting the Nigerian rainfall pattern.

Objectives

1. To compare the annual variations in precipitation across Geopolitical Zones.
2. To investigate the pattern of precipitation across Geopolitical Zones.
3. To build a time-series model that displays the trajectory of precipitation across Geopolitical Zones.

2.0 Methodology

2.1 Descriptive Analysis

The dataset for this study was obtained from NASA Data Access viewer. It consists of Nigeria rainfall (mm) data from the year1981 to 2021 The R- software was used for the analysis and the data summary was done to obtain some basic statistics which include: the mean, minimum value, maximum value, standard deviation, coefficient of variation. The time plot and line graphs were used for data visualization.

2.2 Mann-Kendall Trend Test

The non-parametric rank-based Mann-Kendall (MK) test was used to determine the monotonic trends in rainfall dataset. The condition that must be met before the MK test can be conducted is given by:

$$X = f(t) + \varepsilon_t \quad \text{……(1)}$$

Where f(t) is a continuous monotonic increasing or decreasing function of time. The residual, ε_t, can be assumed to be from the same distribution with zero mean. The MK test statistic, S is calculated by:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k) \quad \text{……(2)}$$

where n is the length of the time series $x_1, \ldots, x_n$; $sign(\cdot)$ is a sign function; and x_j and x_k are values in year j and k, respectively.

The variance of S for series without trend and is given by:

$$\sigma^2(S) = \frac{1}{s} n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p - 1)(2t_p + 5) \quad \text{……(3)}$$

where q is the number of groups tied and t_p is the number of data values in group p. Since, in a non-parametric test, no assumption as to the underlying distribution of data is important, the test statistic Z is then calculated as:

$$z = \frac{s-1}{\sqrt{\sigma^2(s)}} \quad \text{……(4)}$$

2.3 The Autoregressive Integrated Moving Average, ARIMA (p, d, and q) Model

The Autoregressive Integrated Moving Average (ARIMA) model is a versatile time series analysis technique used to analyse and forecast sequential data patterns. Its three components, Autoregressive (AR), Integrated (I), and Moving Average (MA), are represented by parameters p, d, and q. The AR component models relationships between the current and past values of the time series, the integrated component addresses stationarity through differencing, and the MA component accounts for the relationships between the current value of the series and the residual (which is a white noise process). ARIMA is valuable for understanding trends, seasonality, and random noise in data.

Mathematical model for ARIMA:

$$Y_t = \mu + \epsilon_t + \theta_1\epsilon_{t-1} + \cdots + \theta_q\epsilon_{t-q} + \vartheta_d Y_{t-d} + \emptyset_1 Y_{t-1} + \cdots + \emptyset_p \quad \text{……(5)}$$

Y_t - represents the time series variable at time t.

μ – is the intercept.

ϵ_t - is a white noise process

$\emptyset_i,\ \theta_j,\ \vartheta_k$, - are the model parameters for $i, j, k \geq 0$

p - is the order of the autoregressive component.

d **-**is the degree of differencing.

q **-** is the order of the moving average component.

2.4 Model Identification

Model identification is a crucial step in time series analysis, involving processes like visual inspection for patterns, checking stationarity, using autocorrelation and partial autocorrelation plots to determine autoregressive and moving average components, and assessing the need for differencing to achieve stationarity. Model selection and evaluation, often based on criteria like AIC or BIC, guide the choice of parameters. Residual analysis and iterative refinement contribute to selecting the best-fitting model.

2.5 Markov Chain Model

The rainfall dynamics was considered to follow a Markov process. A Markov process is a stochastic process that exhibits the Markov property which states that the future behaviour of the process only depends on its current state and is independent of its past states. Markov processes are used to model a wide range of real-world phenomena that involve sequential transitions with probabilistic behaviour. It is also a mathematical model that describes the evolution of a system where the next state depends only on the current state and is not influenced by the states that precede it.

Let X_t denotes the rainfall amount in month t.

$$P(X_t|X_{t-1}, X_{t-2}, \dots, X_1) = P(X_t|X_{t-1}) \dots\dots (6)$$

For a Markov process in state (i) at time (t), the probability of a transition to a state (j) at time $t + 1$ can be defined as

$$P\left(X_{\{t+1\}} = j \middle| X_t = 1\right) = P_{\{ij\}} \dots\dots (7)$$

A Markov process is considered stationary if the transition probabilities between states do not change with time. More intuitively, a Markov process is stationary if the following assumptions hold:

1. **Homogeneity**: The transition probabilities between states remain constant over time steps.

$$P\left(X_{\{n+1\}} = j \middle| X_n = i\right) = P\left(X_{\{n+m\}} = j \middle| X_{\{n+m-1\}} = i\right) \dots\dots (8)$$

2. **Initial State Distribution:** The distribution of the initial state does not affect the transition probabilities over time.

$$P\left(X_{\{0\}} = i\right) = P\ (X_{\{n\}} = i) \dots\dots (9)$$

The probability in a stationary Markov process gradually stabilizes and loses dependence on the beginning state which describes the concept of ergodicity.

At subsequent time period, the process increases or decreases randomly such that the position of the process at time t follows a random walk, Z_t defined as:

$$Z_t = \begin{cases} -1, & X_{t-1} > X_t \text{ with probability } 1-p \\ 1, & X_{t-1} < X_t \text{ with probability } p \end{cases} \quad \ldots\ldots (10)$$

Where Z_t are independent and identically distributed.

2.6 Long Run Probability Distribution

At the long run the ergodic Markov chain converges to position of statistical equilibrium which is are independent of the starting conditions. Ergodicity defines the equilibrium probability distribution or steady state probabilities which can be determined quite easily. The equation for the limiting distribution is given as:

$$\lim_{n\to\infty} P^n = \pi \quad \ldots\ldots (11)$$

Such that the steady state equilibrium is achieved through:

$$\pi P = \pi \quad \ldots\ldots (12)$$

where $\pi = (\pi_i, i = 1,2 \ldots k)$ is the steady state probability distribution and P is the transition probability matrix and $\sum_i^k \pi_i = 1$

With the Chapman-Kolmogorov equation, the stationary probability distribution of the system can be obtained (Akintunde et al., 2008 and Akintunde et al., 2017). If p_i^0 is the initial probability distribution, then the stationary probability distribution is given as

$$p^n = p_i^0 P^n \quad \ldots\ldots (13)$$

Equation (13) can be obtained using the recursive relation, for $n = 1,2,3, \ldots n$, defined in equation (14) as

$$p^n = p^{n-1} P \quad \ldots\ldots (14)$$

p^n is a probability vector which equals the stead state or stationary probability distribution of the system at time, t_n which is equal the rows of the equilibrium probability matrix, P^n.

3.0 ANALYSIS AND RESULTS INTERPRETATION

3.1 Descriptive Analysis

The descriptive statistics of rainfall for all the 36 states and the Federal Capital Territory during the study period (1981-2021) are presented in the Table 1. From the table the average rainfall ranges from 510.44mm (lowest) around Yobe State in the North-East to

2685.61mm (highest) in Bayelsa a Southern part of the country. Rainfall decreased with increasing latitude, while the coefficient of variation (CV) increased with increasing latitude from the table. This is due to the fact that rainfall amount and latitude have a negative linear correlation, suggesting that precipitation possesses latitudinal zoning. General observation shows that the coefficient of variation of rainfall values recorded in the North (Kano: 41.60%, Kaduna: 68.77%, Bauchi: 57.84%) are higher than those recorded in the South (Enugu: 25.74%, Ogun: 20.24% and Oyo: 18.15%), this implies that the southern region tends to experience more stable rainfall compared to the northern part of the country. Kaduna with a CV of 68.77 percent, has precipitation in the range 532.62 – 7400.77 (mm) per year (mean: 1563.43 ± 1075.12 (mm) per year), while Kebbi with CV of 14.41%, experienced precipitation in the range 590.63 – 970.30 (mm) per year (mean: 778.21 ± 112.18 (mm) per year). This is an indication that the two states (Kaduna and Kebbi), have different rainfall patterns despite being in the same region.

Figure 1 is the time plot of the average rainfall. It shows that the average rainfall is stationary since there is no apparent trend in the plot. In Figure 2, the boxplot shows that there is no presence of outliers in the data and the histogram plot shows from its bell structure that the data is normally distributed.

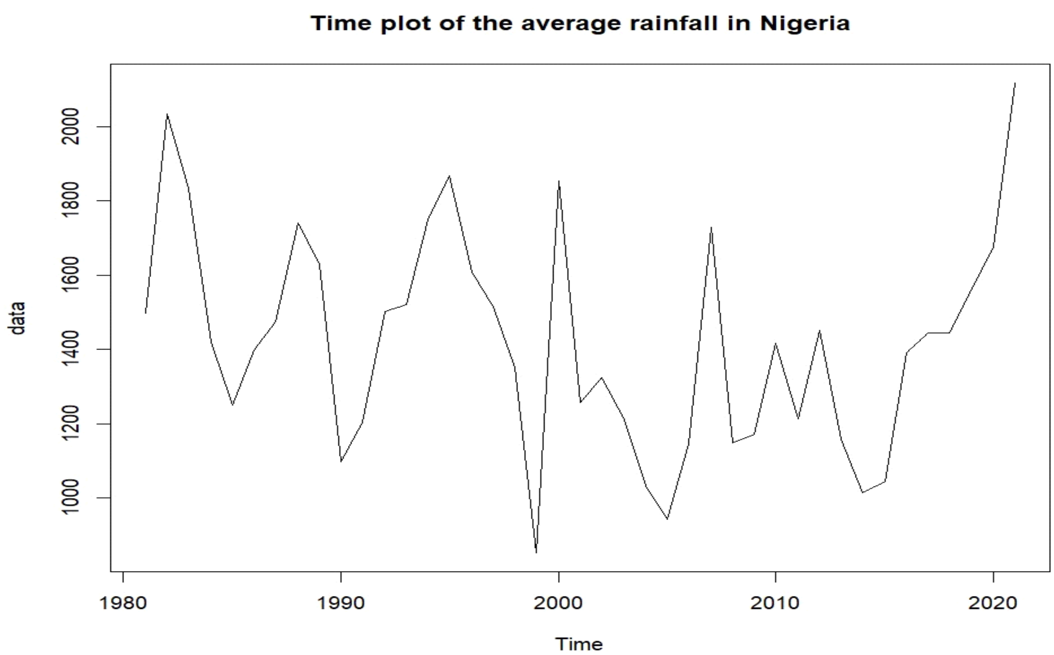

Figure 1: Time plot of average rainfall (1981 – 2021)

Table 1: Descriptive Statistics

States	Min (mm)	Max (mm)	Mean (mm)	Std Dev (mm)	Cv (%)	States	Min (mm)	Max (mm)	Mean (mm)	Std Dev (mm)	Cv (%)
Abia	1096.87	3485.75	1898.26	483.67	25.48	Katsina	395.50	2249.45	742.85	321.93	43.34
Adamawa	769.92	2578.70	1159.00	299.23	25.82	Kebbi	590.63	970.30	778.21	112.18	14.41
Akwa Ibom	1439.64	4983.41	2423.42	653.99	26.99	Kogi	342.76	2207.34	1335.28	390.13	29.22
Anambra	696.09	3032.22	1677.80	518.57	30.91	Kwara	564.25	1788.51	1086.48	246.56	22.69
Bauchi	311.12	3304.28	838.81	485.15	57.84	Lagos	870.12	2278.13	1544.70	340.15	22.02
Bayelsa	1186.53	5605.67	2685.61	921.84	34.33	Nasarawa	569.54	2072.46	1311.56	391.57	29.86
Benue	769.93	2262.29	1332.70	321.25	24.10	Niger	580.08	2215.92	1278.77	331.62	25.93
Borno	379.68	912.31	621.60	136.89	22.02	Ogun	928.13	2225.39	1589.38	321.66	20.24
Cross River	1269.41	4424.43	2125.03	596.39	28.07	Ondo	922.86	2473.69	1741.92	359.57	20.64
Delta	975.60	3543.76	2000.74	638.45	31.91	Osun	1017.77	2832.92	1652.93	344.29	20.83
Ebonyi	937.39	3675.59	1763.61	484.67	27.48	Oyo	938.66	2301.37	1484.72	269.45	18.15
Edo	780.48	3090.22	1836.73	567.09	30.87	Plateau	453.51	1729.69	1105.91	344.57	31.16
Ekiti	849.03	2770.22	1581.56	350.77	22.18	Rivers	1212.89	5726.94	2618.07	899.24	34.35
Enugu	885.94	2699.99	1600.31	411.93	25.74	Sokoto	342.76	1248.28	602.68	193.24	32.06
Gombe	527.35	2222.89	931.67	305.79	32.82	Taraba	1133.78	2541.80	1627.67	318.22	19.55
Imo	954.50	3459.37	2039.00	632.63	31.03	Yobe	295.31	1137.10	510.44	151.23	29.63
Jigawa	279.49	1489.45	575.76	211.59	36.75	Zamfara	263.67	1250.30	814.82	214.55	26.33
Kaduna	532.62	7400.77	1563.43	1075.12	68.77	Fct	400.78	2199.04	1408.60	425.49	30.21
Kano	200.39	1845.69	709.34	295.09	41.60						

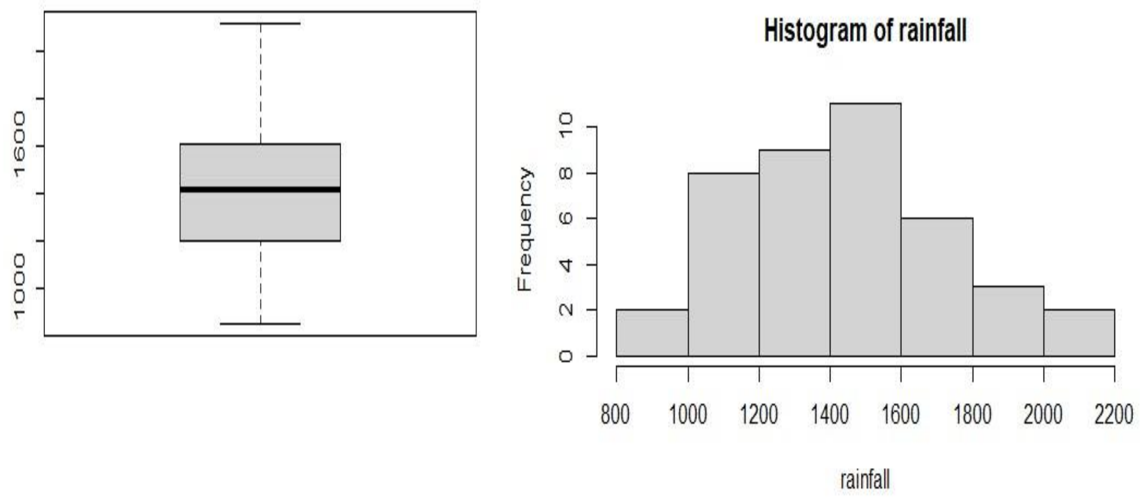

Figure 2: Box Plot and Histogram of average rainfall in Nigeria.

3.2 Annual precipitation Time Series

Figure (3) – (9) are the time series plots of the 36 states and the FCT as considered in this study. The time series plots give simple but first-hand information about each state. The plots show clearly the pattern of rainfall on a yearly basis between 1981 and 2021. The results indicate an increasing trend in almost all the stations in the South (Ogun, Ekiti, Imo), while the Northern states (Sokoto, Zamfara, Kaduna, etc.) are characterized by a stationary trend. The graphs also show a sharp increase and decrease in rainfall amount in all the states within some years. This sudden fall and rise in rainfall values usually makes farming activities in Nigeria a difficult task, as most farmers depends on precipitation particularly in the South. Further information indicates dry spells occurring in all the stations.

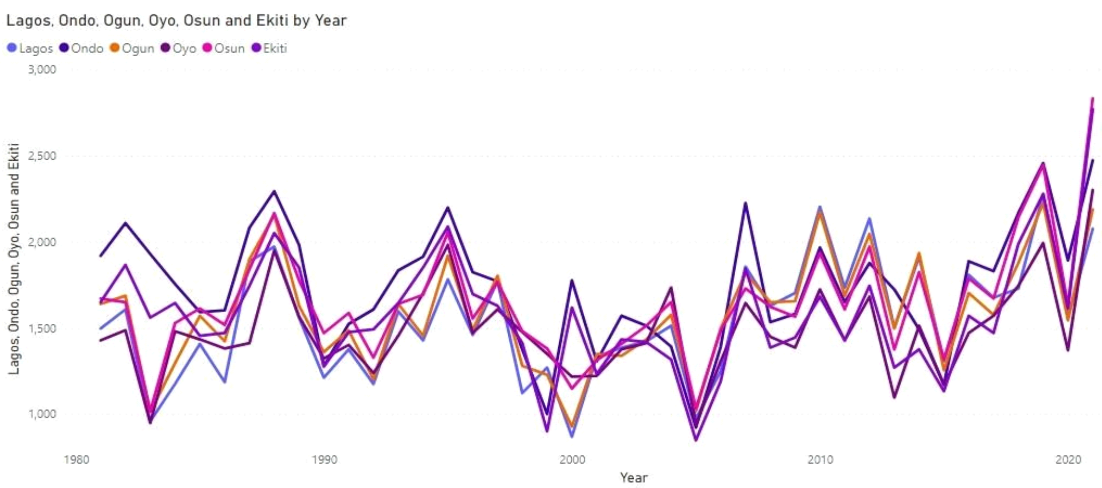

Figure 3: Pattern of Rainfall in South West between 1981 and 2021

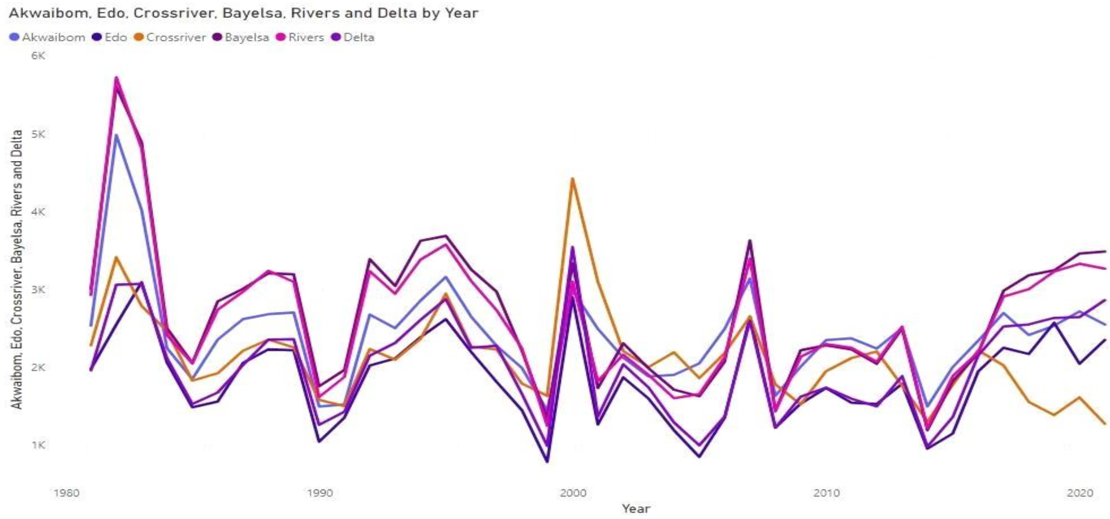

Figure 4: Pattern of Rainfall in South-South between 1981 and 2021

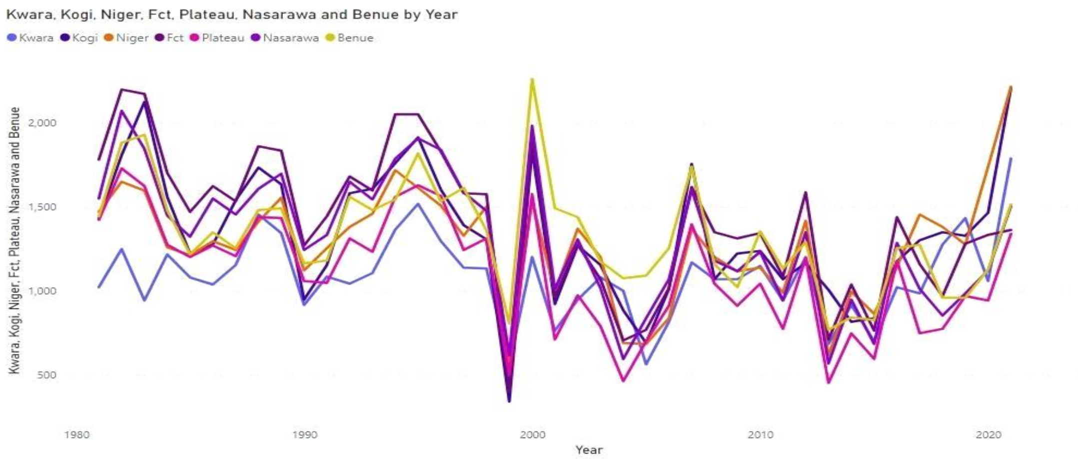

Figure 5: Pattern of Rainfall in North Central between 1981 and 2021

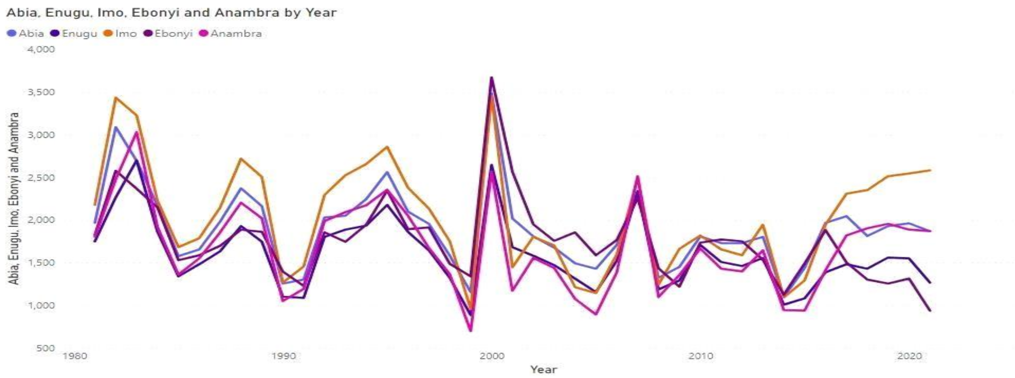

Figure 6: Pattern of Rainfall in South East between 1981 and 2021

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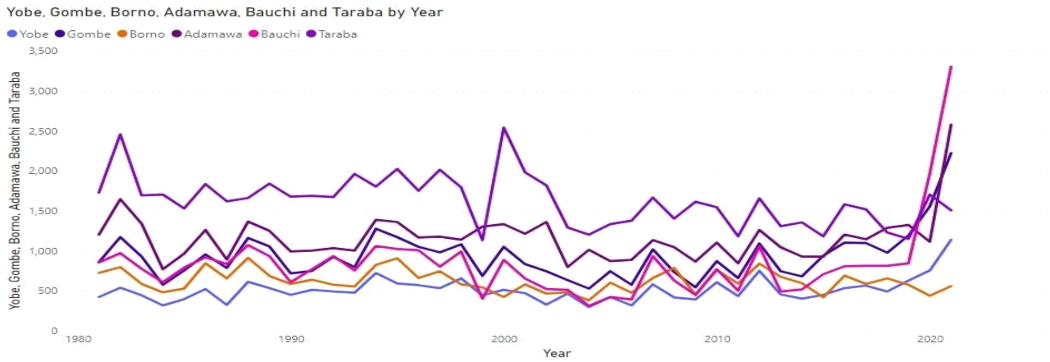

Figure 7: Pattern of Rainfall in North East between 1981 and 2021

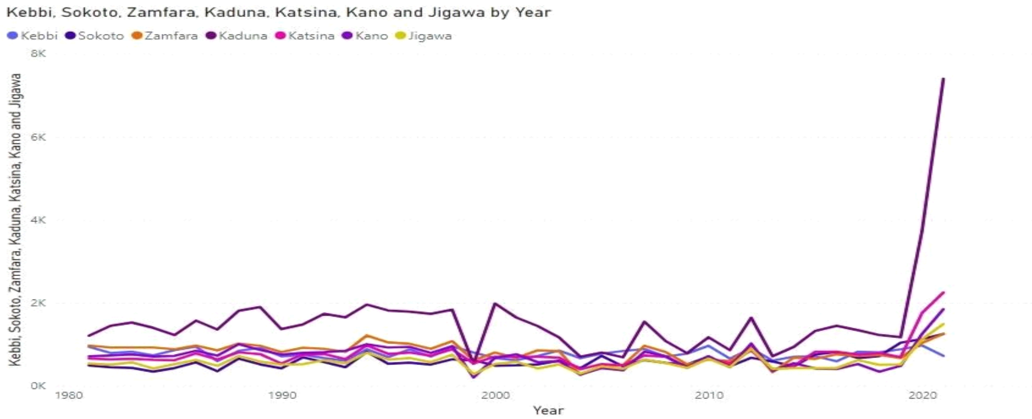

Figure 8: Pattern of Rainfall in North West between 1981 and 2021

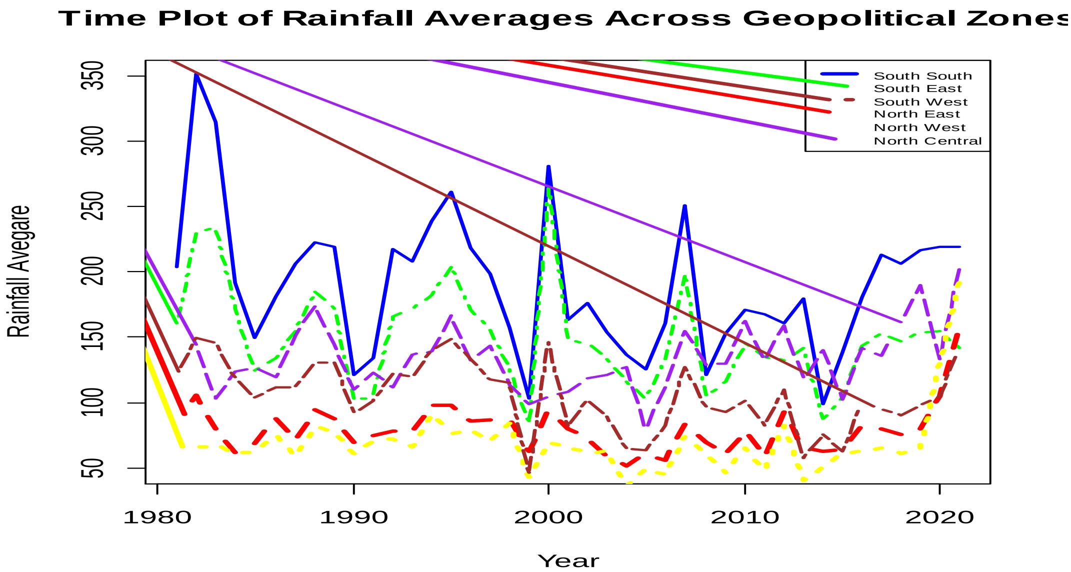

Figure 9: Pattern of Rainfall across geopolitical zones between 1981 and 2021

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3.3 Monthly Precipitation Trends

The results of the Mann-Kendall test (Zs) on precipitation trends and the coefficient of linear regression at the 5% significance level for January-December between 1981 and 2021 are presented in Figures 10 to 15. Positively significant trends in precipitation were observed in most of South-West states, while South-South, North-Central, South-East, North-East except Yobe state, and North-West except Sokoto state had a negatively significant trend. These trends indicate that there are fluctuations in the precipitation pattern all over Nigeria. Most of the changes occurred between the months of April to November.

SOUTH WEST

Osun	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	0.46	0.00	not significant
FEB	no trend	0.60	0.00	not significant
MAR	no trend	0.51	-0.46	not significant
APR	no trend	0.58	-0.38	not significant
MAY	no trend	0.81	0.00	not significant
JUN	no trend	0.63	0.56	not significant
JUL	no trend	0.13	2.07	not significant
AUG	no trend	0.99	0.00	not significant
SEP	no trend	0.16	2.02	not significant
OCT	no trend	0.30	1.42	not significant
NOV	increasing	0.00	1.34	significant
DEC	no trend	0.58	0.00	not significant

Lagos	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	0.12	0.00	not significant
FEB	no trend	0.35	0.00	not significant
MAR	no trend	0.70	0.26	not significant
APR	no trend	0.30	-0.83	not significant
MAY	no trend	0.54	0.67	not significant
JUN	no trend	0.95	0.00	not significant
JUL	increasing	0.02	3.36	significant
AUG	no trend	0.42	0.88	not significant
SEP	increasing	0.02	3.31	significant
OCT	no trend	0.11	1.95	not significant
NOV	increasing	0.00	2.40	significant
DEC	no trend	0.40	0.00	not significant

Ogun	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	0.21	0.00	not significant
FEB	no trend	0.57	0.00	not significant
MAR	no trend	0.80	0.00	not significant
APR	no trend	0.21	-0.88	not significant
MAY	no trend	0.87	0.00	not significant
JUN	no trend	0.83	-0.20	not significant
JUL	no trend	0.07	2.81	not significant
AUG	no trend	0.98	0.00	not significant
SEP	no trend	0.12	2.64	not significant
OCT	no trend	0.53	0.77	not significant
NOV	increasing	0.00	1.76	significant
DEC	no trend	0.61	0.00	not significant

Ondo	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	0.46	0.00	not significant
FEB	no trend	0.81	0.00	not significant
MAR	no trend	0.34	-0.63	not significant
APR	no trend	0.18	-1.19	not significant
MAY	no trend	0.36	-0.62	not significant
JUN	no trend	0.75	-0.82	not significant
JUL	no trend	0.26	1.22	not significant
AUG	no trend	0.69	0.58	not significant
SEP	no trend	0.43	1.40	not significant
OCT	no trend	0.44	-0.99	not significant
NOV	increasing	0.00	1.84	significant
DEC	no trend	0.25	0.00	not significant

Oyo	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	0.54	0.00	not significant
FEB	no trend	0.76	0.00	not significant
MAR	no trend	1.00	0.00	not significant
APR	no trend	0.79	-0.16	not significant
MAY	no trend	0.86	0.00	not significant
JUN	no trend	0.69	0.21	not significant
JUL	no trend	0.86	0.08	not significant
AUG	no trend	0.41	-1.01	not significant
SEP	no trend	0.09	2.05	not significant
OCT	increasing	0.02	2.11	significant
NOV	increasing	0.00	0.56	significant
DEC	no trend	0.93	0.00	not significant

Ekiti	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	0.95	0.00	not significant
FEB	no trend	0.93	0.00	not significant
MAR	no trend	0.13	-0.88	not significant
APR	no trend	0.22	-0.99	not significant
MAY	no trend	0.16	-0.79	not significant
JUN	no trend	0.68	-0.41	not significant
JUL	no trend	0.64	0.54	not significant
AUG	no trend	0.80	-0.38	not significant
SEP	no trend	0.43	0.71	not significant
OCT	no trend	0.81	-0.04	not significant
NOV	increasing	0.00	0.81	significant
DEC	no trend	0.32	0.00	not significant

Figure 10: Precipitation trends of South-West

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SOUTH SOUTH

Rivers	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	0.65	0.00	not significant
FEB	no trend	0.15	-0.48	not significant
MAR	no trend	0.38	-1.12	not significant
APR	decreasing	0.03	-3.04	significant
MAY	no trend	0.12	-1.98	not significant
JUN	no trend	0.54	-1.93	not significant
JUL	no trend	0.57	-0.95	not significant
AUG	no trend	0.78	-1.05	not significant
SEP	no trend	0.72	-0.89	not significant
OCT	decreasing	0.04	-4.76	significant
NOV	no trend	0.46	0.79	not significant
DEC	no trend	0.54	0.00	not significant

Edo	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	0.28	0.00	not significant
FEB	no trend	0.61	0.00	not significant
MAR	no trend	0.46	-0.76	not significant
APR	no trend	0.23	-1.54	not significant
MAY	decreasing	0.01	-2.37	significant
JUN	no trend	0.72	-1.02	not significant
JUL	no trend	1.00	0.00	not significant
AUG	no trend	0.87	0.30	not significant
SEP	no trend	0.59	0.98	not significant
OCT	no trend	0.16	-1.98	not significant
NOV	increasing	0.01	1.65	significant
DEC	no trend	0.59	0.00	not significant

Akwa Ibom	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	0.81	0.00	not significant
FEB	no trend	0.56	-0.16	not significant
MAR	no trend	0.73	-0.32	not significant
APR	no trend	0.08	-1.80	not significant
MAY	decreasing	0.05	-1.88	significant
JUN	no trend	0.64	-1.26	not significant
JUL	no trend	0.81	-0.52	not significant
AUG	no trend	0.80	0.81	not significant
SEP	no trend	0.92	0.00	not significant
OCT	no trend	0.12	-2.82	not significant
NOV	no trend	0.39	0.91	not significant
DEC	no trend	0.75	0.00	not significant

Crossriver	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	0.42	0.00	not significant
FEB	no trend	0.66	0.00	not significant
MAR	no trend	0.36	-0.95	not significant
APR	decreasing	0.03	-1.93	significant
MAY	decreasing	0.00	-3.11	significant
JUN	no trend	0.24	-1.99	not significant
JUL	no trend	0.15	-1.78	not significant
AUG	no trend	0.44	-1.30	not significant
SEP	no trend	0.07	-2.67	not significant
OCT	decreasing	0.00	-4.81	significant
NOV	no trend	0.30	0.75	not significant
DEC	no trend	0.40	0.00	not significant

Bayelsa	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	0.59	0.00	not significant
FEB	no trend	0.23	-0.48	not significant
MAR	no trend	0.63	-0.64	not significant
APR	decreasing	0.04	-3.01	significant
MAY	no trend	0.13	-1.84	not significant
JUN	no trend	0.51	-2.43	not significant
JUL	no trend	0.56	-1.41	not significant
AUG	no trend	0.64	-1.59	not significant
SEP	no trend	0.67	-0.98	not significant
OCT	decreasing	0.01	-5.27	significant
NOV	no trend	0.32	1.05	not significant
DEC	no trend	0.97	0.00	not significant

Delta	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	0.66	0.00	not significant
FEB	no trend	0.61	0.00	not significant
MAR	no trend	0.94	0.00	not significant
APR	no trend	0.29	-1.39	not significant
MAY	no trend	0.16	-1.65	not significant
JUN	no trend	0.71	-1.08	not significant
JUL	no trend	0.98	0.00	not significant
AUG	no trend	0.95	0.00	not significant
SEP	no trend	0.78	0.49	not significant
OCT	no trend	0.17	-2.13	not significant
NOV	increasing	0.01	1.83	significant
DEC	no trend	0.45	0.00	not significant

Figure 11: Precipitation trends of South-South

NORTH CENTRAL

Benue	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	0.18	0.00	not significant
FEB	no trend	0.34	0.00	not significant
MAR	no trend	0.24	-0.32	not significant
APR	no trend	0.71	-0.27	not significant
MAY	decreasing	0.00	-2.26	significant
JUN	decreasing	0.03	-2.34	significant
JUL	decreasing	0.02	-2.40	significant
AUG	decreasing	0.03	-2.40	significant
SEP	decreasing	0.01	-2.46	significant
OCT	no trend	0.15	-0.94	not significant
NOV	no trend	0.55	0.00	not significant
DEC	no trend	0.60	0.00	not significant

Kwara	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	0.29	0.00	not significant
FEB	no trend	0.99	0.00	not significant
MAR	no trend	0.06	-0.50	not significant
APR	no trend	0.15	-0.75	not significant
MAY	no trend	0.19	-0.84	not significant
JUN	no trend	0.53	-0.47	not significant
JUL	no trend	0.26	-1.04	not significant
AUG	no trend	0.89	-0.08	not significant
SEP	no trend	0.80	0.05	not significant
OCT	no trend	0.64	0.25	not significant
NOV	no trend	0.46	0.00	not significant
DEC	no trend	0.52	0.00	not significant

Niger	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	0.61	0.00	not significant
FEB	no trend	0.26	0.00	not significant
MAR	decreasing	0.03	-0.16	significant
APR	no trend	0.30	-0.71	not significant
MAY	no trend	0.23	-0.88	not significant
JUN	no trend	0.09	-1.76	not significant
JUL	decreasing	0.03	-2.31	significant
AUG	no trend	0.36	-0.96	not significant
SEP	no trend	0.57	-0.53	not significant
OCT	no trend	0.30	-0.59	not significant
NOV	no trend	0.65	0.00	not significant
DEC	no trend	0.47	0.00	not significant

Kogi	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	0.24	0.00	not significant
FEB	no trend	0.09	0.00	not significant
MAR	no trend	0.05	-0.81	not significant
APR	no trend	0.16	-1.32	not significant
MAY	decreasing	0.01	-1.59	significant
JUN	no trend	0.06	-2.13	not significant
JUL	no trend	0.36	-1.11	not significant
AUG	no trend	0.89	-0.20	not significant
SEP	no trend	0.38	-0.81	not significant
OCT	no trend	0.31	-1.05	not significant
NOV	no trend	0.19	0.19	not significant
DEC	no trend	0.28	0.00	not significant

Fct	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	0.76	0.00	not significant
FEB	no trend	0.52	0.00	not significant
MAR	decreasing	0.01	-0.41	significant
APR	decreasing	0.02	-1.92	significant
MAY	decreasing	0.00	-3.30	significant
JUN	decreasing	0.02	-2.64	significant
JUL	decreasing	0.04	-2.88	significant
AUG	no trend	0.26	-1.93	not significant
SEP	decreasing	0.00	-3.77	significant
OCT	decreasing	0.02	-2.04	significant
NOV	no trend	0.40	0.00	not significant
DEC	no trend	0.31	0.00	not significant

Plateau	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	1.00	0.00	not significant
FEB	no trend	0.69	0.00	not significant
MAR	no trend	0.12	0.00	not significant
APR	decreasing	0.02	-1.50	significant
MAY	decreasing	0.00	-3.14	significant
JUN	decreasing	0.02	-2.25	significant
JUL	no trend	0.07	-2.40	not significant
AUG	no trend	0.07	-2.64	not significant
SEP	decreasing	0.00	-3.16	significant
OCT	decreasing	0.05	-1.54	significant
NOV	no trend	0.44	0.00	not significant
DEC	no trend	0.10	0.00	not significant

Nasarawa	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	0.58	0.00	ot significant
FEB	no trend	0.55	0.00	ot significant
MAR	no trend	0.22	0.00	ot significant
APR	no trend	0.05	-1.49	ot significant
MAY	decreasing	0.00	-3.10	significant
JUN	decreasing	0.04	-2.33	significant
JUL	decreasing	0.03	-2.76	significant
AUG	decreasing	0.02	-3.06	significant
SEP	decreasing	0.00	-4.17	significant
OCT	decreasing	0.02	-2.03	significant
NOV	no trend	0.75	0.00	ot significant
DEC	no trend	0.67	0.00	ot significant

Figure 12: Precipitation trends of North-Central

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SOUTH EAST

Abia	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	0.68	0.00	not significant
FEB	no trend	0.23	-0.22	not significant
MAR	no trend	0.41	-0.74	not significant
APR	no trend	0.05	-1.76	not significant
MAY	decreasing	0.02	-1.47	significant
JUN	no trend	0.47	-1.27	not significant
JUL	no trend	0.84	-0.21	not significant
AUG	no trend	0.90	0.24	not significant
SEP	no trend	0.41	-1.32	not significant
OCT	decreasing	0.05	-2.98	significant
NOV	increasing	0.02	1.70	significant
DEC	no trend	0.58	0.00	not significant

Imo	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	0.69	0.00	not significant
FEB	no trend	0.10	-0.32	not significant
MAR	no trend	0.49	-0.66	not significant
APR	no trend	0.12	-1.98	not significant
MAY	no trend	0.08	-1.76	not significant
JUN	no trend	0.59	-1.32	not significant
JUL	no trend	0.75	-0.44	not significant
AUG	no trend	0.86	-0.60	not significant
SEP	no trend	0.54	-1.24	not significant
OCT	decreasing	0.04	-3.59	significant
NOV	increasing	0.02	1.95	significant
DEC	no trend	0.52	0.00	not significant

Enugu	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	0.99	0.00	not significant
FEB	no trend	0.18	0.00	not significant
MAR	no trend	0.10	-0.99	not significant
APR	decreasing	0.04	-1.72	significant
MAY	decreasing	0.01	-2.26	significant
JUN	no trend	0.16	-1.76	not significant
JUL	no trend	0.62	-0.60	not significant
AUG	no trend	0.91	-0.27	not significant
SEP	no trend	0.64	-0.60	not significant
OCT	decreasing	0.00	-3.28	significant
NOV	no trend	0.08	0.59	not significant
DEC	no trend	0.79	0.00	not significant

Ebonyi	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	0.43	0.00	not significant
FEB	no trend	0.76	0.00	not significant
MAR	no trend	0.25	-0.93	not significant
APR	decreasing	0.01	-1.94	significant
MAY	decreasing	0.00	-2.43	significant
JUN	no trend	0.32	-1.26	not significant
JUL	no trend	0.17	-1.32	not significant
AUG	no trend	0.32	-1.42	not significant
SEP	no trend	0.11	-1.95	not significant
OCT	decreasing	0.00	-3.96	significant
NOV	no trend	0.32	0.58	not significant
DEC	no trend	0.54	0.00	not significant

Anambra	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	0.94	0.00	not significant
FEB	no trend	0.27	0.00	not significant
MAR	no trend	0.17	-0.97	not significant
APR	no trend	0.09	-1.65	not significant
MAY	decreasing	0.00	-2.32	significant
JUN	no trend	0.19	-2.08	not significant
JUL	no trend	0.82	-0.32	not significant
AUG	no trend	0.72	0.66	not significant
SEP	no trend	0.92	0.09	not significant
OCT	decreasing	0.04	-2.98	significant
NOV	increasing	0.04	0.97	significant
DEC	no trend	0.78	0.00	not significant

Figure 13: Precipitation trends of South-East

NORTH EAST

Taraba	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	0.53	0.00	not significant
FEB	no trend	0.90	0.00	not significant
MAR	no trend	0.10	-0.23	not significant
APR	no trend	0.63	-0.31	not significant
MAY	decreasing	0.04	-1.76	significant
JUN	no trend	0.12	-1.86	not significant
JUL	decreasing	0.01	-1.85	significant
AUG	decreasing	0.01	-3.23	significant
SEP	decreasing	0.00	-2.53	significant
OCT	decreasing	0.00	-2.55	significant
NOV	no trend	0.39	0.00	not significant
DEC	no trend	0.71	0.00	not significant

Gombe	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	1.00	0.00	not significant
FEB	no trend	0.12	0.00	not significant
MAR	no trend	0.81	0.00	not significant
APR	no trend	0.39	0.00	not significant
MAY	no trend	0.87	0.00	not significant
JUN	no trend	0.97	0.00	not significant
JUL	no trend	0.51	-0.61	not significant
AUG	increasing	0.03	2.32	significant
SEP	no trend	0.09	1.24	not significant
OCT	no trend	0.05	-0.68	not significant
NOV	decreasing	0.03	0.00	significant
DEC	no trend	0.10	0.00	not significant

Borno	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	1.00	0.00	not significant
FEB	no trend	1.00	0.00	not significant
MAR	no trend	0.07	0.00	not significant
APR	no trend	0.05	0.00	not significant
MAY	no trend	0.11	-0.47	not significant
JUN	no trend	0.77	-0.20	not significant
JUL	no trend	0.13	-1.00	not significant
AUG	no trend	0.77	-0.08	not significant
SEP	no trend	0.92	0.00	not significant
OCT	no trend	0.49	-0.04	not significant
NOV	no trend	0.82	0.00	not significant
DEC	no trend	1.00	0.00	not significant

Bauchi	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	1.00	0.00	not significant
FEB	no trend	0.12	0.00	not significant
MAR	no trend	0.62	0.00	not significant
APR	no trend	0.12	-0.38	not significant
MAY	no trend	0.32	-0.49	not significant
JUN	decreasing	0.05	-1.68	significant
JUL	no trend	0.22	-1.17	not significant
AUG	no trend	0.18	1.76	not significant
SEP	no trend	0.96	0.00	not significant
OCT	decreasing	0.01	-1.03	significant
NOV	no trend	0.05	0.00	not significant
DEC	no trend	0.10	0.00	not significant

Yobe	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	1.00	0.00	not significant
FEB	no trend	1.00	0.00	not significant
MAR	no trend	0.16	0.00	not significant
APR	no trend	0.06	0.00	not significant
MAY	no trend	0.14	-0.23	not significant
JUN	no trend	0.54	0.37	not significant
JUL	no trend	0.55	-0.40	not significant
AUG	increasing	0.01	2.20	significant
SEP	increasing	0.04	0.74	significant
OCT	no trend	0.70	0.00	not significant
NOV	no trend	0.12	0.00	not significant
DEC	no trend	1.00	0.00	not significant

Adamawa	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	1.00	0.00	not significant
FEB	no trend	0.81	0.00	not significant
MAR	no trend	0.20	0.00	not significant
APR	no trend	0.55	-0.15	not significant
MAY	no trend	0.38	-0.53	not significant
JUN	no trend	0.96	0.00	not significant
JUL	no trend	0.18	-1.27	not significant
AUG	no trend	0.12	1.58	not significant
SEP	no trend	0.79	0.16	not significant
OCT	no trend	0.06	-0.88	not significant
NOV	no trend	0.84	0.00	not significant
DEC	no trend	0.91	0.00	not significant

Figure 14: Precipitation trends of North-East

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NORTH WEST

Kebbi	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	1.00	0.00	not significant
FEB	no trend	0.20	0.00	not significant
MAR	no trend	0.84	0.00	not significant
APR	decreasing	0.02	-0.36	significant
MAY	decreasing	0.03	-0.97	significant
JUN	no trend	0.09	-1.05	not significant
JUL	no trend	0.14	-0.66	not significant
AUG	no trend	0.05	1.70	not significant
SEP	no trend	0.46	0.53	not significant
OCT	no trend	0.06	0.66	not significant
NOV	no trend	1.00	0.00	not significant
DEC	no trend	1.00	0.00	not significant

Zamfara	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	1.00	0.00	not significant
FEB	no trend	1.00	0.00	not significant
MAR	no trend	0.51	0.00	not significant
APR	no trend	0.06	-0.53	not significant
MAY	decreasing	0.00	-1.51	significant
JUN	decreasing	0.01	-1.68	significant
JUL	decreasing	0.02	-2.07	significant
AUG	no trend	0.72	-0.34	not significant
SEP	decreasing	0.05	-1.14	significant
OCT	no trend	0.87	0.00	not significant
NOV	decreasing	0.01	0.00	significant
DEC	no trend	1.00	0.00	not significant

Kaduna	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	1.00	0.00	not significant
FEB	no trend	0.61	0.00	not significant
MAR	no trend	0.79	0.00	not significant
APR	no trend	0.12	-0.89	not significant
MAY	no trend	0.46	-0.88	not significant
JUN	no trend	0.10	-2.17	not significant
JUL	no trend	0.50	-1.15	not significant
AUG	no trend	0.78	-0.43	not significant
SEP	no trend	0.30	-1.14	not significant
OCT	no trend	0.07	-1.05	not significant
NOV	no trend	0.57	0.00	not significant
DEC	no trend	0.59	0.00	not significant

Kano	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	1.00	0.00	not significant
FEB	no trend	1.00	0.00	not significant
MAR	no trend	0.47	0.00	not significant
APR	decreasing	0.01	-0.46	significant
MAY	decreasing	0.01	-1.25	significant
JUN	decreasing	0.03	-1.63	significant
JUL	decreasing	0.04	-2.18	significant
AUG	no trend	0.62	-0.77	not significant
SEP	decreasing	0.02	-1.91	significant
OCT	no trend	0.07	-0.42	not significant
NOV	decreasing	0.03	0.00	significant
DEC	no trend	0.10	0.00	not significant

Katsina	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	1.00	0.00	not significant
FEB	no trend	1.00	0.00	not significant
MAR	no trend	0.76	0.00	not significant
APR	no trend	0.47	0.00	not significant
MAY	no trend	0.25	-0.41	not significant
JUN	no trend	0.41	0.44	not significant
JUL	no trend	0.97	0.00	not significant
AUG	no trend	0.20	0.93	not significant
SEP	no trend	0.60	-0.26	not significant
OCT	no trend	0.44	0.00	not significant
NOV	decreasing	0.03	0.00	significant
DEC	no trend	1.00	0.00	not significant

Sokoto	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	1.00	0.00	not significant
FEB	no trend	1.00	0.00	not significant
MAR	no trend	0.79	0.00	not significant
APR	no trend	0.55	0.00	not significant
MAY	no trend	0.60	0.00	not significant
JUN	no trend	0.12	0.70	not significant
JUL	no trend	0.13	1.15	not significant
AUG	increasing	0.00	3.34	significant
SEP	increasing	0.01	1.62	significant
OCT	increasing	0.01	0.26	significant
NOV	no trend	1.00	0.00	not significant
DEC	no trend	1.00	0.00	not significant

Jigawa	Trend	P-Value	Sen's Slope	Significance
JAN	no trend	1.00	0.00	not significant
FEB	no trend	1.00	0.00	not significant
MAR	no trend	0.59	0.00	not significant
APR	no trend	0.42	0.00	not significant
MAY	no trend	0.22	-0.30	not significant
JUN	no trend	0.85	0.00	not significant
JUL	no trend	0.18	-0.75	not significant
AUG	no trend	0.12	1.71	not significant
SEP	no trend	1.00	0.00	not significant
OCT	no trend	0.94	0.00	not significant
NOV	decreasing	0.03	0.00	significant
DEC	no trend	1.00	0.00	not significant

Figure 15: Precipitation trends of North-Wes

3.4 Modelling annual average rainfall

The Markov model is the basis of this analysis, hence the model for the average rainfall was developed with the Markov model. Random fluctuation in the observation was defined as a binomial process so as to generate the realization of the rainfall process. The realization is Z_j is such that:

$$Z_j = \begin{cases} 1 \ \ for\ X_j > X_i \text{ with probability } p \\ -1 \ \ for\ X_j < X_i \text{ with probability } q \end{cases}$$

Where X_j and X_i are two consecutive observations from the average annual rainfall data.

Table 2. Distribution of the realization (average annual rainfall)

	Z_j	Probability
Increase in average rainfall	1	0.56
Decrease in average rainfall	-1	0.44

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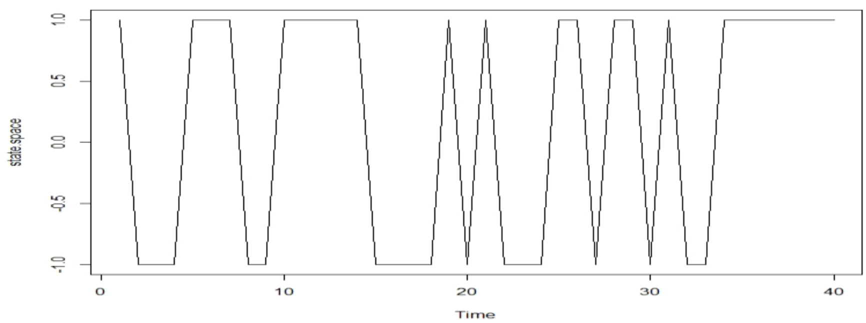

Figure 16: Plot of the realization of the average annual rainfall

Figure 16 shows the trajectory path of the realization which exhibit a random walk pattern

3.5 Absolute/Stationary Probability Distribution

From our random walk, the distribution of the generating function is binomial with an initial probability distribution given as:

$P^0 = (0.560, 0.440)$ ……………………………………………………………..(15)

and the transition probability matrix is given in equation (16)

$P_{ij} = \begin{pmatrix} 0.64 & 0.36 \\ 0.47 & 0.53 \end{pmatrix}$………………………………………………………………….(16)

Using the Chapman-Kolmogorov equation recursively, the distribution converges to the fixed probability vector which is equals the absolute probability distribution of the system at the long run as shown in Table 3. Hence the steady state probability distribution of the system which does not depend on the number of steps obtains as: $P^{(n)}$ = (0.5662651, 0.4337349).

Table 3. Absolute probability distribution of average rainfall

n	$P(_1n)$	$P(_2n)$
1	0.5788	0.4212
2	0.568396	0.431604
3	0.568396	0.431604
4	0.5666273	0.4333727
5	0.5663266	0.4336734
6	0.5662755	0.4337245
7	0.5662668	0.4337332
8	0.5662654	0.4337346
9	0.5662651	0.4337349
10	0.5662651	0.4337349

3.6 Model identification

3.6.1 correlogram

Table 4 shows the ACF and PACF of the process and figures 17 and 18 are their corresponding correlograms. A lack of slow decay pattern in the ACF and PACF plot, indicates that the

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process is stationary. The ACF plot cuts off after lag 1, this suggests a moving average model of order 1 [*MA (1)*]. The correlogram of the PACF also shows a sharp cut off after lag 1, this suggests an Autoregressive model of order 1 [*AR (1)*]. Hence the two correlograms suggests that *ARIMA (1,0,1)* is adequate.

Table 4: ACF and PACF of average rainfall

Lag	0	1	2	3	4	5	6	7	8	9	10	11	12
ACF	1	0.337	0.093	-0.001	-0.042	0.107	0.122	0.05	-0.156	-0.019	-0.064	-0.018	0.145
PACF		0.337	-0.023	-0.028	-0.035	0.153	0.047	-0.023	-0.2	0.136	-0.097	0.009	0.137

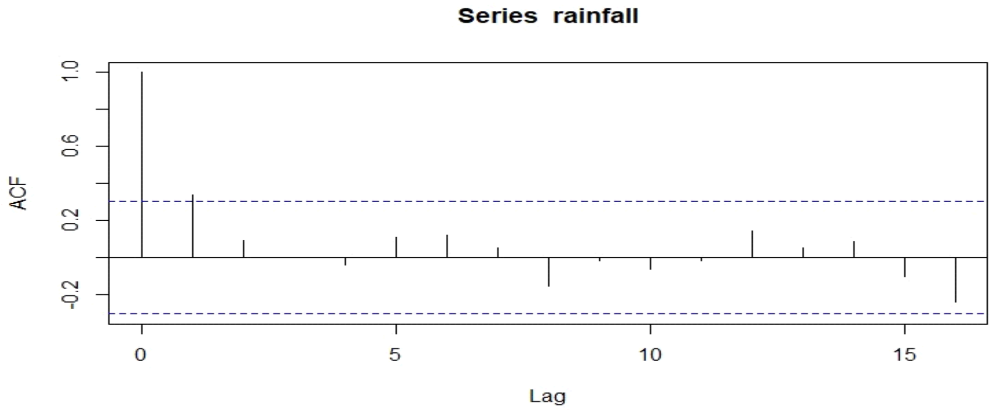

Figure 17: ACF of the average rainfall

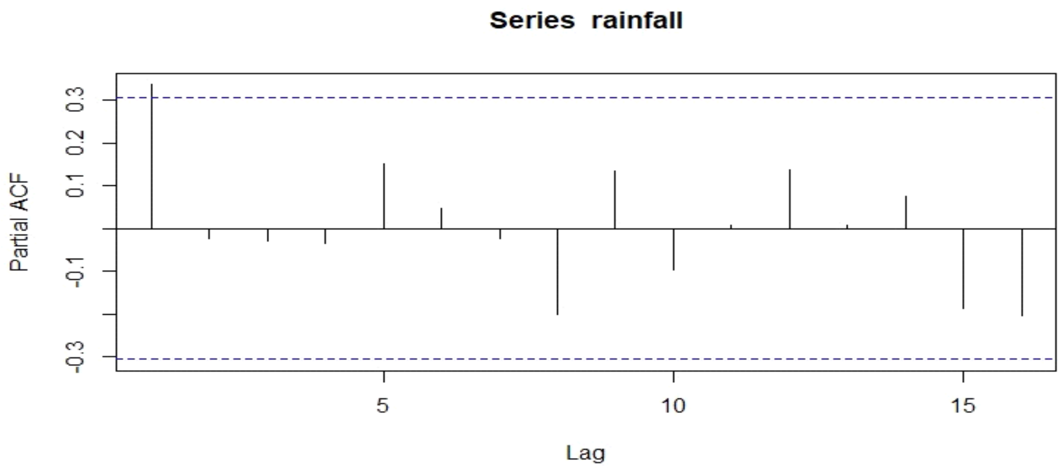

*Figure 18: P*ACF of the average rainfall

3.6.2 Model selection criteria

The model information criterion adopted in this study is Akaike's Information Criterion (AIC). The essence of a model selection criterion in modelling is to provide a guide in selecting an appropriate model for a process, so as to boycott error that may arise due to overfitting or underfitting.

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Table 5 displayed some ARIMA models with parameter *d=0.* The model with the least AIC is *ARIMA (1,0,0)*, hence it is considered the best fit for the average annual rainfall pattern.

Table 5: AIC of ARIMA (p,d,q) models for the average rainfall

Model	AIC	Log Likelihood
ARIMA(0,0,1)	583.1028	-288.55
ARIMA(2,0,0)	584.6054	-288.3
ARIMA(1,0,1)	584.6064	-288.3
ARIMA(2,0,1)	586.5999	-288.3
ARIMA(1,0,0)	582.62	-288.31

Table 6: Parameters of the identified model

	$\boldsymbol{\mu}$	$\emptyset_{\mathbf{1}}$
Estimate	0.1583	0.1654
Standard error of estimate	0.1840	0.1569

The identified model for the rainfall pattern in this study is:

$$X_t = 0.1583 + 0.1654X_{t-1} + \varepsilon_t \quad (17)$$

The residual analysis shows that the suggested ARIMA model is satisfactory for forecasting averaging monthly rainfall since the histogram of the residual (Figure 19) shows that the residuals are normally distributed. The overall test of model accuracy is provided by Ljung-Box test statistics Figure (20). The Ljung-Box test statistics is also known as the Box-Pierce chi-square statistics, it contains the portmanteau statistics with their associated p-values. Almost all plots are based on the examination of the residuals. Hence the model ARIMA (1,0,0) is the optimal ARIMA model and adequate for the data since the p-values falls within the allowable limit.

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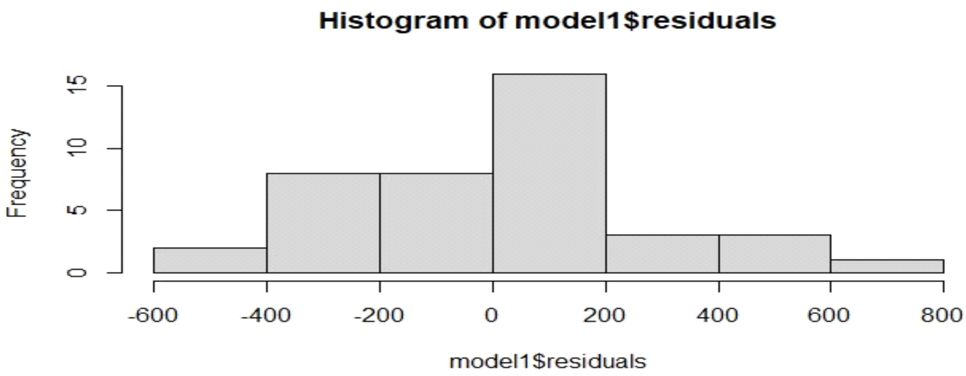

Figure 19: Histogram of Residuals

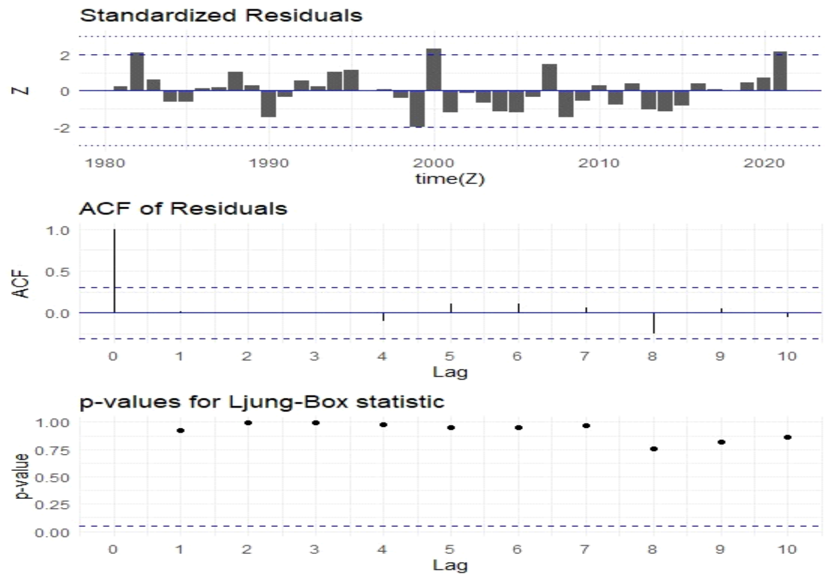

Figure 20: Ljung-Box test statistics

Figure 21 shows the forecast of the Nigeria average rainfall. The plot shows that monthly average rainfall in Nigeria is likely to decrease.

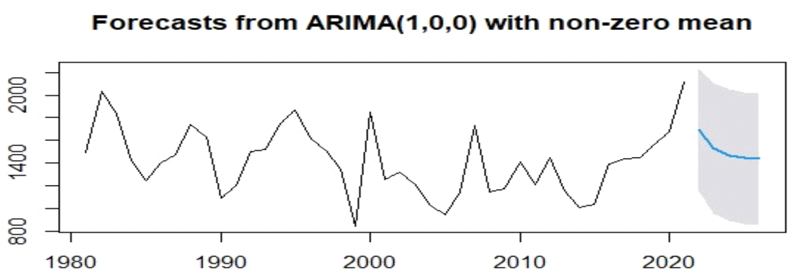

Figure 21: Forecast of Average rainfall from AR(1) model

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4.0 Conclusion

Monthly analysis of precipitation series suggests that many of the states in the South and some in the North experienced increasing trend in rainfall, while states such as Jigawa, Kano, Kebbi, Sokoto were stationary; however, in general, the trend analysis shows that Nigeria experienced an increasing trend in rainfall amount. This could be attributed to the increase in rainfall amount recorded in the first 20 years (2001–2021) of the 21st century as against the decreased rainfall amount recorded in the last two decades of the 20th century, while on the annual time scale, most of the 37 states showed a significant trend. This shows that the trend has changed drastically, with many states now witnessing greater annual rainfall, but with high variability within the rainy months of the year. This may be attributed to the effect of climate change on the climatology of Nigeria. Then modelling the annual average rainfall as a dynamical system, the Kolmogorov method of absolute probability shows that the average rainfall is ergodic and that annual rainfall will at the long run reduce with a probability of occurrence being 44%, this is also confirmed from 5 years forecast of the time series analysis. The use of stochastic dynamics of rainfall alongside the trend analysis gave a general overview of the expected situation on the long run. The study concludes that in addition to trend analysis, rainfall dynamics decision makers need to employ the stochastic modelling of the process for better informed decisions and necessary actions to mitigate climate change and natural disasters. The change in the pattern of rainfall has led to widespread extreme events, such as drought – recorded in the Southern and in North-Central parts of Nigeria and a reduction in the length of the growing season across the country. Such prolonged variability in rainfall may have a significant effect on the groundwater resources and the hydrology of Nigeria. Therefore, it is recommended that farmers should adopt crops that are drought resistant and early maturing especially in the Northern region of the country. This can be achieved by improving and developing agricultural technologies that are environmental and drought sensitive. Other adaptive measures for climate include users adjusting their farming calendars for irrigated agriculture according to the changing rainfall period. It is believed that these recommendations among others could help avert the impending food insecurity in Nigeria, particularly as the population has been predicted to double by the year 2050.

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REFERENCES

Abdullahi, A.C, Abdullah, A.M, Bose, M.M, Kasim, I. Mande, K., & Harun, R. (2015). Rainfall Trend Detection in Northern Nigeria over the Period of 1970-2012: *Journal of Environment and Earth Science 5(2).*

Ajayi, O., Ogunjobi, O. K., & Adesina, A. O. (2018). Trends in Precipitation and Temperature in Nigeria. *International Journal of Climatology*, 38(10), 3744-3759.

Akintunde A.A., Agwuegbo S. O. N. and Olayiwola O. M. (2017). Markov Models For The Analysis Of Dynamical Systems. *Journal of Natural Sciences Engineering and Technology* 16(1), 35-49

Akintunde, A.A., Asiribo, O.E., Adebanji, A.O., Adelakun, A.A., Agwuegbo, S.O.N. (2008). Stochastic Modelling of Daily Precipitation of Daily Precipitation in Abeokuta Proceedings of International Conference on Science and National Development. 108-118. College of natural Sciences COLNAS, UNAAB, Abeokuta

Feng, X; Liu, C; Xie, F; Lu, J; Chiu, LS; Tintera, G; Chen, B (2019). Precipitation characteristic changes due to global warming in a high resolution (16 km) ECMWF simulation. Quarterly Journal of Royal Meteorology Society, 145(718): 303-317

Laux, P., Jackel, G., Tingem, R.M. and Kunstmann, H. (2010). Impact of climate change on agricultural productivity under rainfed conditions in Cameroon –A method to improve attainable crop yields by planting date adaptations. *Agricultural and Forest Meteorology*, 150: 1258-1271

Mudita, C.C., Richardson-Kageler, S.J. and Murungu F.S. (2008). Performance of maize (Zea mays L.) and Soya beans [Glycine max (L) Merrill] Cultivars of varying growth habit in intercrop in sub-humid environments of Zimbabwe. *Journal of Agronomy*, 7: 229-236

Nnaji, C.C., Mama, C.N. and Ukpabi, O. (2014). Heierarchical Analysis of rainfall variability across Nigeria. Theoretical and Applied Climatology, doi:10.1007/s00704-014-1348-z

Odjugo P.A.O. (2005). An analysis of rainfall patterns in Nigeria. Global Journal of Environmental Sciences, 4(2): 139-146

ISSN NUMBER: 1116-249X

Oguntade E.S., Babalola, T.K. and Oladimeji D.M. (2024). Modelling Nigeria rainfall data using exponential family of distribution: A comparative study. Dutse Journal of Pure and Applied Sciences, 10(2b): 144-152.

Ojo O. S. and Ogunjo S. T. (2022). Machine learning models for prediction of rainfall over Nigeria. Scientific African, 16 https://doi.org/10.1016/j.sciaf.2022.e01246

Omogbai B.E. (2010). Rain days and their predictability in South Western region of Nigeria. Journal of Human Ecology, 31: 185-195

Tabari, H. (2020). Climate change impact on flood and extreme precipitation increases with water availability. Scientific Reports, 10 https://doi.org/10.1038/s41598-020-70816-2

ISSN NUMBER: 1116-249X